Remote Sampling and Survey of Shallow Water Using AUVs with Application to Mine Reconnaissance; Support for Experiments Using the FAU UUVs

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1 LONG-TERM GOALS

.Having made an important shift in tactical focus from the traditional global conflict to regional conflict, the U.S. Navy is increasingly focused on the projection of power from sea to land by expanding its regional warfare capabilities into littoral regions which involve operations to and from the near land ocean. To support the power transfer mechanism in littoral regions cluttered with mines, the Navy has recognized a critical need to develop and/or acquire enabling technology with which to carry out sea mine reconnaissance, detection, classification and neutralization operations in littoral environments without imposing unnecessary risk of personnel safety.

2 OBJECTIVES

The primary goal of this project is, through an orchestrated scientific experiment, to both characterize the remote sampling performance using multiple small AUVs for coastal mine reconnaissance tasks, and the effect of environment on navigation, communications, and object detection sensors. We wish to quantify the performance of the sensor systems and platforms in relation to environmental conditions and sea state. In the experiment, mine-like objects will be deployed, and a sequence of tasks will be carried out with regard to characterizing the environment, design survey based on environment feedback and detecting of mine-like objects.

The second objective of this project is to provide operations support for the development of sensor payloads for the Ocean Explorer AUVs.

3 APPROACH

FAU has developed small modular AUV platforms and accompanying sensor, communication, and navigation systems which are appropriate for remote mine Reconnaissance and environmental characterization tasks in shallow water. Small AUVs have size, power, computation, and speed limitations that make single pass mine reconnaissance impractical given current technology. However the lower operating and deployment costs for small vehicles makes a multi-pass approach feasible. In this approach one or more AUVs perform repeated surveys. Each survey serves to identify those areas where a more focused higher resolution survey is needed and rule out areas where no further survey is needed. Because spatial resolution of the imaging sensors is a function of range one can get high spatial resolutions if the range is short enough. The hypothesis

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is that for comparable cost multiple inexpensive vehicles can achieve coverage rate comparable to large vehicles. The remote mine reconnaissance task can be broken down into the following stages: Rapid environmental assessment, mine detection, mine classification, mine identification, mine localization and revisitation.

Although several different Navigation and vehicle positioning systems have been integrated into Two modes of navigation were employed for this experiment. In one mode of operation the AUV dead reckoned under water using DVL based ground speed and heading to calculate its position. The AUV periodically surfaces to obtain DGPS fixes to bound the drift in its position estimate. The second type of navigation used in the experiment is long base line (LBL) sonar.

As part of the South Florida Ocean Measurement Center in Ft. Lauderdale Florida, a shallow water range with mines was set up for a series of MCM experiments using the FAU AUVs. The first experiment was conducted December of 1998. The planned objective was to quantify the performance of the Ocean Explorer AUV for mine reconnaissance tasks such as rapid environmental assessment, remote search, remote classification and remote identification of mine like objects both moored in the water column and laying on the sea floor. The primary sensors used for this test were high frequency side scan and ambient light video. In addition, a forward look sonar and a laser line scanner were fielded. A CTD and DVL/ADCP provide environmental data. The AUV first conducted a wide area side scan survey and environmental assessment. The AUV then returned and its data uploaded. Human operators post processed the side scan and manually detected and classified targets. The AUV was then programmed to revisit the targets and perform close in multiple sensor sweeps with side scan and video of each target. Manual post processing and analysis of this data provided sufficient information for more accurate classification and even identification of targets. This project will repeat similar experiments in November and December of 1999 including an attempt at on-line target detection and multiple AUV operations.

4 WORK COMPLETED

4.1 MCM

The 1998 Mine Counter Measure experiments (MCM) took place off Ft. Lauderdale from December 1to December 12. All missions were conducted from the Research Vessel Sea Diver in the Navy Range site approximately 2 NM South of Port Everglades Inlet in 20 - 70 ft. of water depth. An LBL array consisting transponders at 9.5 kHz and 11.0 kHz was deployed in the Navy Range. The survey area consisted of a 500 meter by 500 meter box with side roughly aligned to North-South East-West respectively. The mines were deployed in 2 North-south lines near the western (shallow) end of the box. There were a total of 19 mines of various shapes and one torpedo.

During the 1998 MCM Experiment, 22 missions were run with the Drake and Magellan OEX AUVs. Three basic mission types were used as follows: 1) Wide area grid survey of a 500 meter box with both North-South and East-West legs at 25 meter spacing and at 5 meters altitude; 2) Targeted grid survey of a 50 meter box with both North-South and East-West legs at 10 meter spacing and at 2.5 meter altitude for bottom targets and higher altitude for moored targets. 3) Swim over surveys at 2.5 to 4 meter altitude with 3 - 5 meter spacing parallel to the track line. Several other types of missions were conducted to test navigation and vehicle systems in preparation for the reconnaissance missions. All the missions were run at a water speed of 2.5 knots. A diagram of the OEX side scan configuration is shown in Figure 4.1 below.

4.2 Operations Support

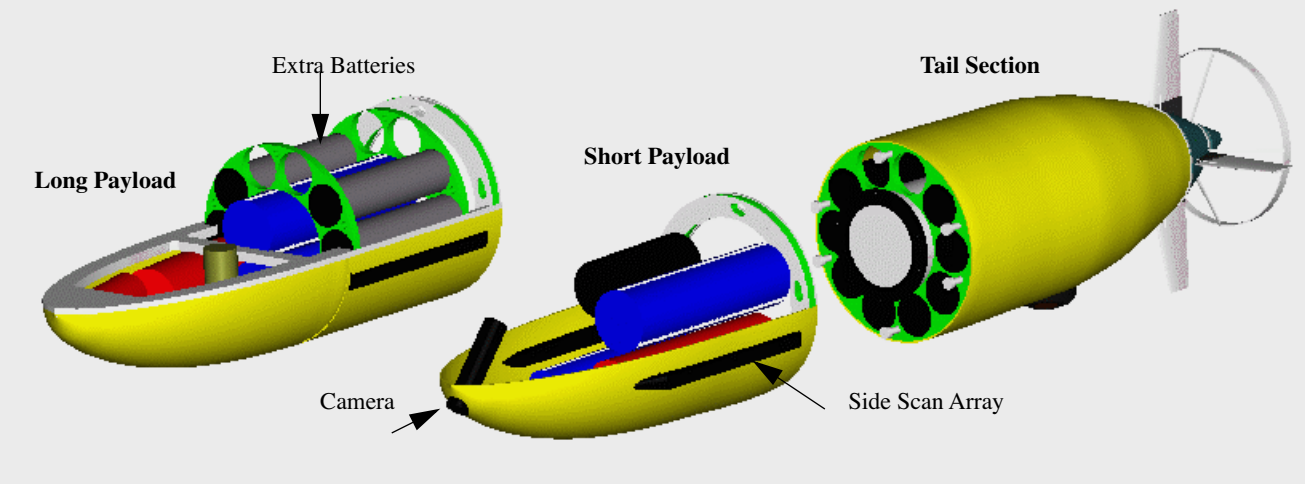
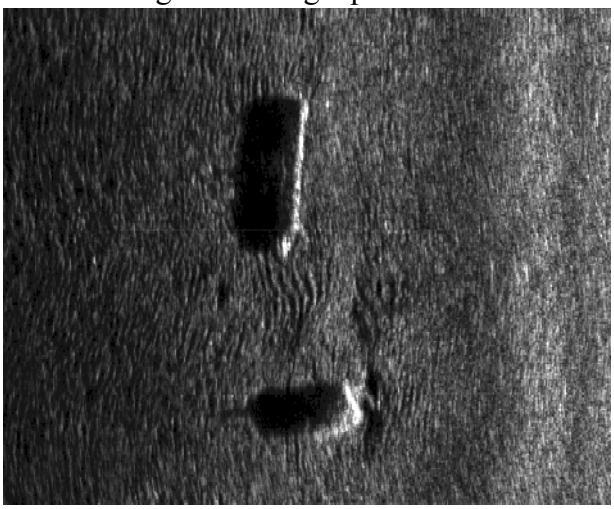


Figure 4.1 Cut -away view of the payloads used for the mine reconnaissance experiment along with a tail section. Any payload can attach to any tail section.

The operations part of this project supported several at sea experiments in 1998 including, CoBop, the 4 D current experiment, noise measurements at Lake Pend O Reille, Sarasota Florida mission, and other short experiments. The results of those missions will be reported by the respective PIs running the experiments

5 RESULTS

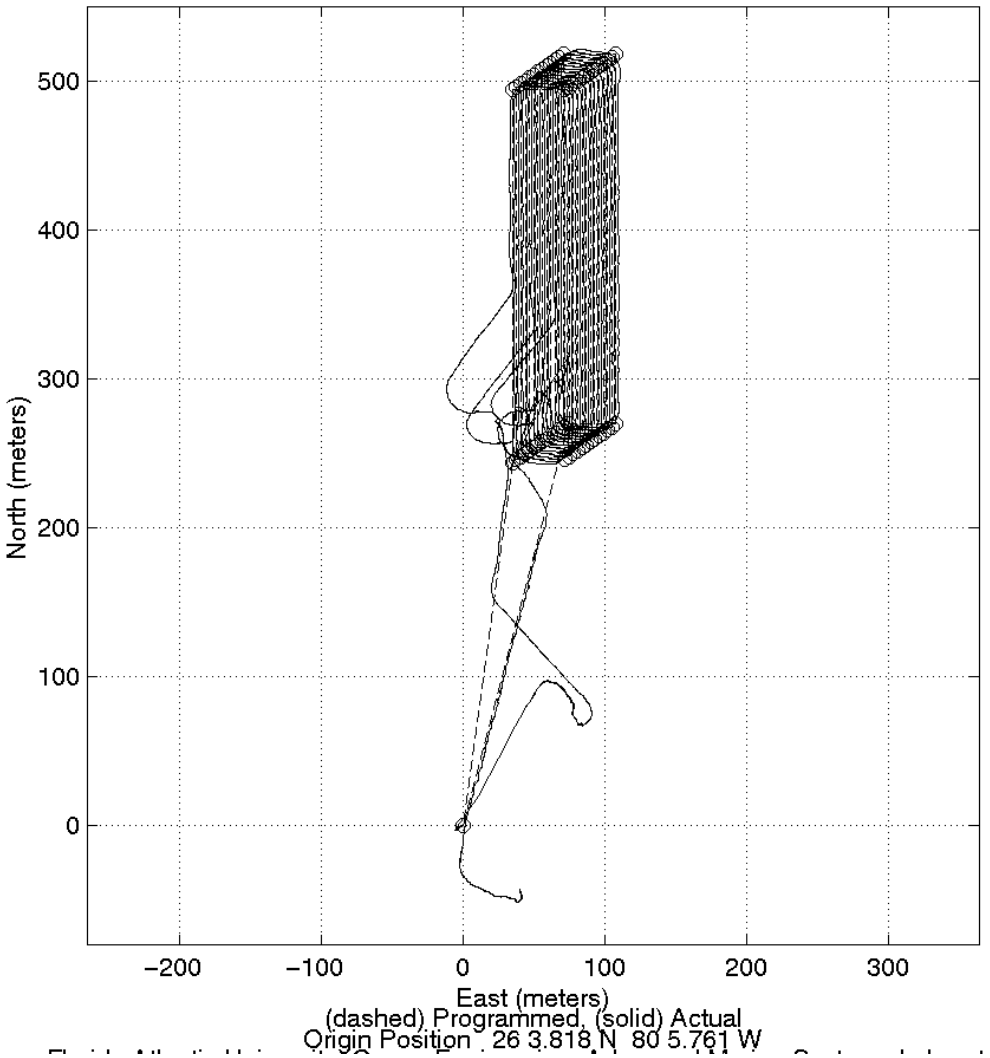
The most significant result of the MCM experiment is that we demonstrated that shallow water mine reconnaissance could be conducted completely remotely using inexpensive small vehicle platforms. The combination of HFSS and Video enable detection, classification, and identification. Shown below is a side scan image and a target plot.



6 IMPACT/APPLICATIONS

.The success of the MCM experiment helped to facilitate the adoption by ONR of Organic MCM capability as part of its future Naval capabilities goals. These systems are planned to participate in FBE-H exercises in 2000.

(a)



7 TRANSITIONS

Nato SACLANT is acquiring two Ocean Explorer vehicles for the purpose of developing advanced sonar systems for shallow water mine reconnaissance. It is anticipated the much of the associated technology will be commercialized in the next year.

8 RELATED PROJECTS

Coordination of Experiments Using AUVs at the SFTF, ONR.

AUV Hydrodynamics in Shallow Water during Adverse Weather Conditions, ONR.

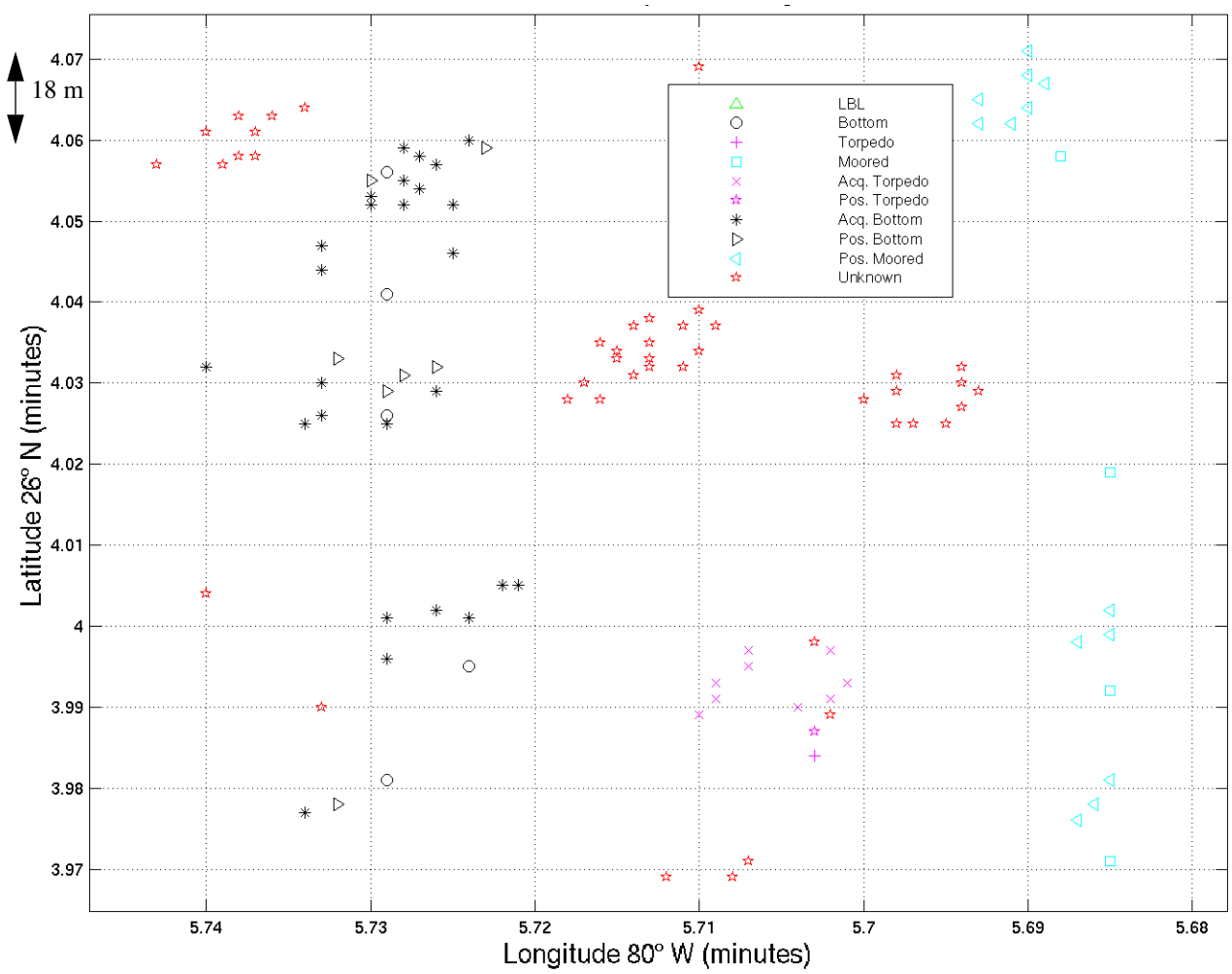
Acoustic Communications with AUVs and AOSN Development

AUV Navigation and Platform Development

Remote Sampling and Survey of Shallow Water Using AUVs w/application to Mine Reconnaissance and operations support for experiments using the FAU AUVs.

Sampling and Survey with AUVs in Adverse Weather Conditions

ONR MURI on Nonlinear Control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9 PUBLICATIONS

P.E. An , M. Dhanak, N. shay, J. Van Leer, Sam Smith, Coastal Oceanography Using a Small AUV, submitted to Journal of Atmospheric and Oceanic Technology, Sept 1998

A. Healey, P.E. An, S.M. Smith, "Multi-Sensor Asynchronous Extended Kalman Filtering for AUV Navigation, Submitted to the IEEE Transactions on Oceanic Engineering.

GS Rae, D. Kronen, S. Smith,FAU Technical Report, Docking Navigation Experiment. September 1999

S. Smith, L. Marquis, S Snowden, FAU Technical Report, MCM Experiment Dec 1998.

S. Smith, L. Marquis, S. Snowden. FAU Technical Report, AUV Fest 1998,

S. Smith, S. Snowden, FAU Technical Report, ACOMS Hawaii Experiment

J. Jalbert, FAU Technical Report, CoBop Experiment

J. Jalbert, FAU Technical Report, 4D Current Experiment

J. Jalbert, FAU Technical Report, Adverse Weather Experiment.

Feijun Song, Samuel Smith, Charbel Rizk, "A General Cell State Space Based TS Type Fuzzy Logic Controller Automatic Rule Extractions and Parameter Optimization Algorithm". IEEE Industrial Electronics Conference, IECON 99 San Jose CA November 29 - December 3rd 1999.

Feijun Song, Samuel Smith, Charbel Rizk, "A Fuzzy Logic Controller Design Methodology for 4D Systems with Optimal Global Performance Using Enhanced Cell State Space Based Best Estimate Directed Search Method",1999 IEEE International Conference on Systems Man and Cybernetics , Tokyo Japan, October 12-15, 1999

Feijun Song, Samuel Smith, Charbel Rizk, "Reducing Memory Requirement of Cell State Space Based Fuzzy Logic Controller Design Approaches Using K-d Trees" 1999 IEEE International Conference on Systems Man and Cybernetics , Tokyo Japan, October 12-15, 1999

Xiaohong Yuan, K. ganesan, Matthew Evett, Samuel M. Smith, "Providing Real-time Data Trajectory Access in Autonomous Underwater Vehicles", Proceeding IEEE Oceans 99 Conference, September 13-16, 1999, Seattle WA

Xiaohong Yuan, K. Ganesan, Scott Snowden, Samuel M. Smith, Matthew Evett, "Mission Command Macros For Autonomous Underwater Vehicles, Proceeding IEEE Oceans 99 Conference, September 13-16, 1999, Seattle WA

Alexandre Delarue, Samuel Smith, Edgar An, "AUV Data Processing and Visualization Using GIS and Internet Techniques", Proceeding IEEE Oceans 99 Conference, September 13-16, 1999, Seattle WA

M. Dhanak, E. An, K. Holappa, S. Smith, "Using Small AUVs for Oceanographic Measurements" Proceeding IEEE Oceans 99 Conference, September 13-16, 1999, Seattle WA

G. Grenon, E. An, S. Smith, "Enhancement of the Inertial Navigation System" Proceeding IEEE Oceans 99 Conference, September 13-16, 1999, Seattle WA

D. Mallinson, D. Naar, A. Hine, S. Smith, S. Schock, d. Wilson and G. Gelfenbaum, "Seafloor Mapping and Target Identification Using AUVs: Applied AUV Experiments, UUST 99 Durham NH August 23-25, 1999.

Feijun Song, Samuel Smith, Charbel Rizk, "Optimized Fuzzy Logic Controller Design for 4D Systems Using Cell State Space Technique with Reduced Mapping Error", IEEE Conference On Fuzzy Systems, FUZZ-IEEE 99 Seoul Korea, August 23- 25 1999.

S.M. Smith, D. Kronen, R. Dunn, J. Whitney, J. Frankenfield, E. An, T. Pantelakis, A. Burns, E. Hetzig, "An Ultra Modular Plastic Mini AUV Platform for VSW Mine Reconnaissance". SPIE Aerosense, 1999, Orlando Florida April 5-9, 1999.

S.M. Smith, P.E. An, R. Christiansen, J. Kloske, S. Snowden, D. Kronen, L. Marquis. "Results of an Experiment Using AUVs for Shallow Water Mine Reconnaissance, SPIE Aerosense, 1999, Orlando Florida April 5-9, 1999.

SV, UUVs OE 98 Sept. 1998 Southhampton England